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Canadian Forestry Service | Service canadien des forêts

PROGRAM REVIEW

1984-85

Forest Pest Management Institute

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THE CANADIAN FORESTRY SERVICE

GOVERNMENT OF CANADA

The Canadian Forestry Service is the principal source of federal expertise in forestry. Its general objective is to promote the wise management and use of Canada's forest resources for the economic, social, and environmental benefit of Canadians.

The following are the main functions of the CFS:

1. Coordination of federal policies, for the promotion of better resource management and forest industry development.

2. Provision of scientific and technological leadership in forestry through research and development.

3. Provision and analysis of national and international statistics and information as a basis for policy formulation.

4. Development and certification of codes and standards for wood product performance.

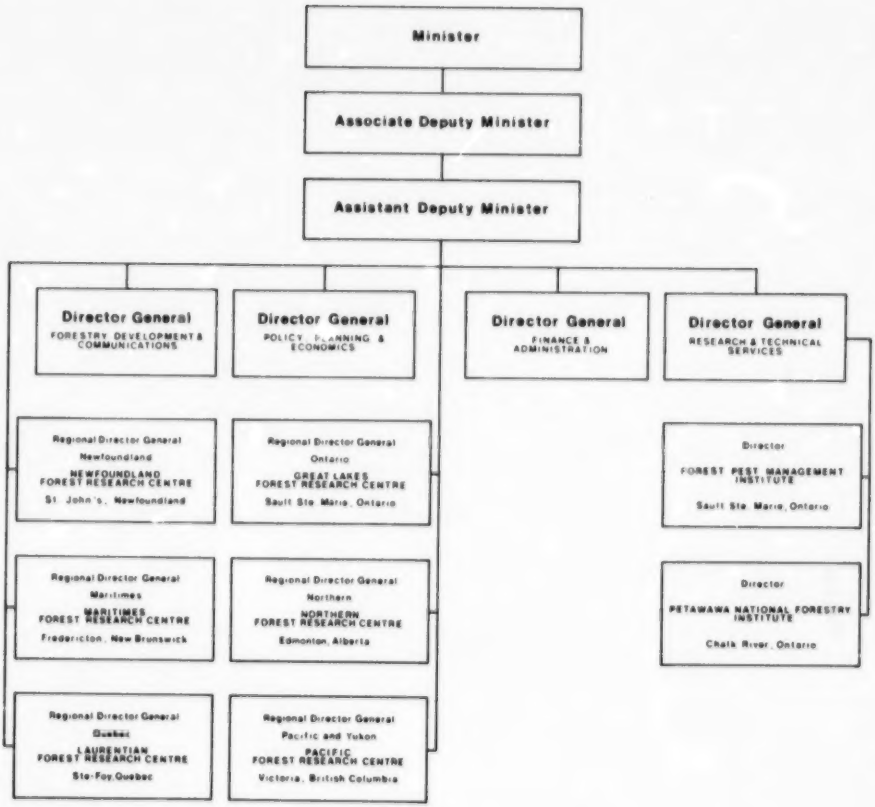
5. Protection of Canada's forests from foreign pests.

6. Fostering the potential use of the forest resource for energy.

7. Contributing to the environmental objectives of the government of Canada.

A number of federal agencies are involved in forestry programs and a Federal Forestry Sector Strategy Committee has been established to coordinate federal forestry activities. The Canadian Forestry Service has been designated the lead agency.

The Canadian Forestry Service is comprised of a headquarters unit, six forest research centres, and two national institutes. The forest research centres are responsive to regional priorities and maintain close liaison with the respective provincial government forestry departments and other clients. They also participate in, and frequently lead, national programs. The national institutes provide the focus for programs of national scope.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SERVICE CANADIEN DES FORÊTS

GOUVERNEMENT DU CANADA

Le Service canadien des forêts (SCF) réunit la majorité des spécialistes fédéraux en foresterie. Son objectif général est de promouvoir l'aménagement et l'utilisation judicieux des ressources forestières du Canada pour le plus grand bien économique, social et environnemental des Canadiens.

Voici les principales fonctions du SCF:

1. Coordonner les politiques fédérales afin de favoriser l'amélioration de la gestion des ressources et l'expansion de l'industrie forestière.

2. Fournir une orientation scientifique et technologique dans le domaine de la foresterie, par la recherche et le développement.

3. Fournir et analyser les statistiques et l'information nationales et internationales qui serviront à établir les politiques.

4. Mettre au point et homologuer des codes et des normes en matière de rendement des produits du bois.

5. Protéger les forêts canadiennes en luttant contre les ravageurs étrangers.

6. Parrainer l'utilisation éventuelle des ressources forestières pour la production d'énergie.

7. Adhérer aux objectifs environnementaux du gouvernement fédéral.

Divers organismes fédéraux participent aux programmes forestiers, et un comité de la stratégie forestière fédérale a été crée pour coordonner les activités fédérales en matière de foresterie. Le SCF a été désigné organisme directeur.

Le Service canadien des forêts comprend une administration centrale, six centres de recherches forestières et deux instituts nationaux. Les centres de recherches forestières doivent répondre aux impératifs régionaux et entretenir une liaison étroite avec les ministère provinciaux des Forêts. Ils participent également à des programmes nationaux dont ils assument fréquemment la direction. Les instituts nationaux sont les foyers des programmes d'envergure nationale.

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Director's Foreword

Canada is a forest nation. Forestry contributes more to our balance of international trade than agriculture, mining, fisheries and fuels combined and provides one in every ten jobs in this country. It is important to our socio-economic well-being that Canada's share of the foreign market in wood and wood products be maintained or increased in the years to come. The truth is, however, that the annual allowable cut for softwoods, by far the most heavily utilized forest component in Canada, is approximately 165 million m^3. When factors such as economic accessibility, failure of natural regeneration, neglect of forest renewal on depleted productive forest lands, losses from fire, insects and diseases and competing vegetation and other factors are taken into consideration, an annual softwood harvest of about 155 million m^3 leaves a very small margin for expanded future utilization. And, in fact, the sustained economic supply of softwoods has been reached, or exceeded, in most provinces, creating severe local problems in some communities that depend almost exclusively on the forest industry for their economic livelihood. It has been realized that massive programs of intensive forest renewal and forest management must be instituted and maintained to rectify this situation. To be successful, these programs must include the development and utilization of genetically superior planting stock, extensive programs of site preparation, suppression of competing vegetation, stand thinning and fertilization where required and more extensive use of forest protection practices to reduce losses from fire, and from destructive insects and diseases. In short, it will require the utilization of all silvicultural tools available to forest managers, the dedication of the forestry community and the support of the Canadian public to attain these important and achievable goals.

The program of the Forest Pest Management Institute addresses one important component of this broader problem - reduction to acceptable levels of losses in forest production caused by destructive forest insects and competing vegetation. These losses, which have been estimated at anywhere between one-half and two-thirds of the average annual harvest, cannot be tolerated and can be reduced through development and judicious use of pest control products. Development of such control products and of strategies for their effective and environmentally benign use is the Forest Pest Management Institute's raison d'être, and is in direct alignment with the overall objective of the Canadian Forestry Service, "to promote the wise management and use of Canada's forest resource for the economic, social and environmental benefit of Canadians".

As a National Institute, FPMI's research interests and mandate transcend regional boundaries. It brings together special expertise, research equipment and facilities that would be difficult to duplicate in regional research centres within the Canadian Forestry Service. Because of this, the Institute's program attempts to support and add depth to pest management programs undertaken by CFS regional forest research centres and is therefore attuned to pest management problems facing provincial forest managers. Obviously, a cooperative approach to the solution of mutual problems is advantageous and, whenever possible, is practiced by the Institute with regional elements of the CFS and provincial forest authorities.

As described in more detail throughout this booklet, somewhat in excess of 50 percent of the Institute's R & D program is concerned with the development of biorational control agents for use against economically important forest insect pests. Within this part of our program we conduct the fundamental and applied research required to develop microbial control agents - bacteria, fungi, viruses and protozoa - for use against forest insect pests; we investigate the use of insect growth regulators and genetic mechanisms for this same purpose; and we investigate the use of insect sex pheromones or sex attractants both for monitoring the occurrence of insect pests and for their control. This biorational control agents research is supported by fundamental research in insect tissue culture, cellular biology, immunochemistry and biological systems analysis essential for the identification of control agents, elucidation of their precise modes of action, development of improved methods for their mass production, and for determination of optimal strategies for their effective use.

A large part of the Institute's program is concerned with the development of chemical insecticides and herbicides for use against destructive forest insect pests and competing vegetation. Until biorational control agents can be developed to their full potential, we will have to rely heavily on these materials as our first line of defense in forestry and, regardless of what developments occur on the biorational side, it is almost certain that we will always have to depend upon chemical pesticides to a certain extent. Research in this area includes the toxicology and screening of new and/or improved insecticides and herbicides for forestry use, determination of their efficacy under field conditions and development of improved methods for utilizing them. To optimize the effectiveness of both chemical and biorational control agents, methods must be developed to deliver them directly to the target area in the precise amounts required to meet protection requirements and to minimize undesirable effects on other components of the forest ecosystem. The Institute is, therefore, significantly involved in application technology

research including the effects of formulation properties on spray cloud emission and behaviour, and the effect of meteorological and other factors on spray cloud behavior from emission to canopy penetration and impaction.

The responsible use of pest control products demands that their use impose minimal risk to the environment or to human health. The effects on human health lie outside the mandate of the Forest Pest Management Institute and are evaluated by appropriate federal and provincial health agencies. The Institute is, however, heavily involved in research on the environmental impact and chemical accountability of pesticides. This research is required to determine the effects of pesticides on non-target organisms in the forest environment and the persistence, dynamic cycling and ultimate fate of these products and their metabolites in the forest ecosystem.

All of these R & D thrusts are supported by a Complementary Services Project, which provides the insect production, plant production and pathogen production services required to facilitate the R & D program.

This Program Review booklet is designed to acquaint the reader broadly with the Forest Pest Management Institute, its mandate and its program. Data generated within the Institute's R & D program are essential for the development of new and/or improved pest control products for forestry use and for development of strategies for their operational use which will optimize effectiveness and minimize adverse environmental impact. In addition, Institute research provides much of the data upon which the registration status of pest control products for forestry use is determined under the Pest Control Products Act and upon which effective yet environmentally benign use patterns are developed and promulgated.

G.W. Green
Director
1 April 1985

Microbial Control Agents

A wide variety of naturally occurring insect pathogens, including bacteria, viruses, fungi, and protozoa, can have adverse effects on the survival and reproduction of forest insect pests. To increase the number of options available to the forest manager for control of economically important insect pests, biological control research at the Institute is aimed at identifying those insect pathogens that have control potential and identifying the conditions under which they can be used to prevent insect outbreaks, or to suppress them once they have occurred. When these conditions have been identified, strategies can be developed for the use of these pathogens, either by themselves or in concert with other control methods such as chemicals.

Institute research into biological control presently concentrates on three main areas; the identification of insect-specific pathogens for control use, the elucidation of the conditions under which these organisms exert their effect on naturally occurring populations, and the development of use patterns and strategies for their effective use. These projects investigate naturally occurring host-pathogen interactions, develop data necessary to support petitions for registration of candidate pathogens, and improve application strategies for registered agents. Research into a particular organism can overlap these categories in terms of understanding its natural occurrence and effectiveness and developing it for use.

FP-10 BACTERIAL PATHOGENS

PROJECT STAFF:

P.G. Fast (Project Leader), Study Leader (Vacant), R. Milne

OBJECTIVES: *To enhance the effectiveness of* Bacillus thuringiensis *and related bacterial pathogens for use in the control of forest insects in Canada.*

ACHIEVEMENTS: Previous work in this project has shown that the toxicity of *Bacillus thuringiensis (B.t.)* resides in the parasporal crystal produced when the bacterium sporulates. The last three instars of spruce budworm have been found to be susceptible to *B.t.* in laboratory and field situations. Cell damage appears to be extensive before feeding inhibition is observed. The effect of *B.t.* on spruce budworm larval mortality is dependent on exposure as well as on dose. Serological and immunological studies have shown that most crystal types generate both specific and nonspecific antibodies, which have been used to provide a grouping technique for strains that has been applied to the typing of over 300 isolates. Enzyme-linked immunoassays have been used to identify isolates with greater specific toxicities than those presently in commercial use.

During 1984-85, equations were generated to describe the effect of concentration combined with droplet size and droplets/needle on efficacy. The cooperative field experiments with MFRC, Forest Protection Ltd. (FPL) New Brunswick Research and Productivity Council (RPC) and the province of Quebec continued, with the goal of evaluating the effect of concentration on efficacy. A cooperative research project, on the biotechnological development of *B.t.* was organized. Those involved are: National Research Council, University of Ottawa, Laurentian University, Waterloo University and the new Biotechnology Research Institute established by the NRC in Montreal.

PROJECTIONS: During 1985-86, the collaborative program with MFRC, FPL, RPC and the province of Quebec will continue. The collaborative inter-institutional research program on the biotechnology of the *B.t.* crystal will come into full operation.

FP-11 FUNGAL PATHOGENS

PROJECT STAFF:

D. Tyrrell (Project Leader), D. Perry (Study Leader), K. Humphries, M. Welton

OBJECTIVES: *To develop methods and procedures for the use of entomogenous fungi in the management of forest insects in Canada.*

ACHIEVEMENTS: Substantial contributions have been made by this project, since the 1950's, to an understanding of the biology of entomogenous fungi. Significant progress has been made toward the development of these fungi as control agents. Resting spore germination has been achieved for five species of entomophthoraceous fungi and many of the factors affecting germination have been determined. The resting spore germination of several *Erynia* species has been described and photoperiod effects have been documented. Epizootiological field studies have demonstrated the importance of such factors as host density and spatial distribution of the host and the effects of inoculum density and weather conditions on the establishment and spread of fungal pathogens. Mathematical models have been designed that describe some of these interactions.

During 1984-85, many new isolates of *Erynia radicans* and *Entomophora aulicae* were obtained from infected spruce budworm. Photoperiod was shown to govern the timing of death in insects infected with *E. aulicae*. A spore clock was built to determine the relationship between time of death and onset and duration of sporulation. Population studies were continued at Black Sturgeon Lake and Lake Superior Provincial Park. Modelling of fungus-environment and fungus-insect interactions continued in collaboration with FP-23.

PROJECTIONS: Physiological and biochemical studies on *Erynia radicans* isolates will continue. Isozyme studies on isolates obtained to date will be completed. Studies on the effects of photoperiod on death of insects infected with *E. aulicae* will continue. And, participation will continue in the joint FPMI/GLFRC population studies at Black Sturgeon Lake and Lake Superior Provincial Park.

FP-12 PROTOZOAN PATHOGENS

PROJECT STAFF:

G.G. Wilson (Project Leader), E. Young

OBJECTIVES: *To investigate the host-parasite relationships of microsporidia and determine their potential and methods for use for control of forest insect pests.*

ACHIEVEMENTS: This project was initiated in 1968, and since that time has made significant progress in elucidating the occurrence and effect of microsporidia in forest insect populations. These parasites were found to have strong debilitating effects on their hosts by reducing adult longevity and fecundity. A quantitative bioassay was developed for microsporidia infecting the spruce budworm and forest tent caterpillar. The microsporidium *P. schubergi* showed promise as a biological control agent for both Lepidopterous and Hymenopterous pest insects.

During 1984-85 experiments to determine the effects of *N. fumiferanae* and *P. schubergi* infection on male and female budworm and the ability of the male to transfer the microsporidia in sperm were completed. In no case did infected males transfer the microsporidia. The study on the effects of intensity of *N. fumiferanae* in female adults and the subsequent effects on offspring continued. Study of interactions between spruce budworm and microsporidia continued at Gargantua and Black Sturgeon Lake.

PROJECTIONS: During 1985-86, the study on the effects of intensity of *N. fumiferanae* in female adult spruce budworm and the subsequent effects on offspring will be completed. The study of the field ecology/population dynamics of spruce budworm as it relates to microsporidian intensity and infection levels will continue. A comparison of the parasitic microsporidia in the jackpine budworm with *N. fumiferanae* of the spruce budworm will be initiated.

FP-13 VIRAL PATHOGENS

PROJECT STAFF:

J.C. Cunningham (Project Leader), B. Arif (Study Leader), W.J. Kaupp (Study Leader), P.B. Jamieson, K. Brown, R. Burke, B. Cunningham.

OBJECTIVES: *To develop viruses for effective and environmentally acceptable use in the population regulation of important forest insect pests.*

ACHIEVEMENTS: For the past 35 years, this project has been devoted to the isolation, biochemical and biophysical characterization and evaluation of control potential of a variety of viruses that affect important forest insect pests. Lecontvirus, for control of redheaded pine sawfly, and Virtuss, for control of Douglas-fir tussock moth, both received temporary registrations under the Pest Control Products Act in 1983. NPVs of the eastern hemlock looper, Bruce spanworm, winter moth, forest tent caterpillar, gypsy moth and balsam fir sawfly have reached the stage of small scale field trials. Methods have been developed to extract, stain, and count viruses in soil samples and on leaf surfaces, and to bioassay them to determine their activity.

A petition for the registration of European pine sawfly NPV was submitted in March 1985. Biochemical characterization of the *Choristoneura fumiferana* NPV revealed that there are host-induced alterations in the viral genome, and that these alterations are different in viruses grown in the eastern and western spruce budworms. The region of the NPV gene coding for polyhedral protein was identified. Epizootiological studies were completed for NPVs of European pine sawfly, redheaded pine sawfly, Douglas-fir tussock moth, spruce budworm, and the gypsy moth.

PROJECTIONS: Virus specific protein synthesis of spruce budworm NPV will be studied in infected cells. Western spruce budworm granulosis virus will be further characterized. Field tests will be carried out using spruce budworm NPV against jack pine budworm. Studies will continue on the effect of droplet size on the efficacy of viruses. The persistence of spruce budworm NPV on foliage and in the soil will be investigated.

Biological Interactions

In a research program as broad as that of the Institute there is an essential requirement for research into the biological effects of a variety of insect pest control methods, and for systems to study modes of action and identification. To conduct such research, and to develop information required for successful conduct of other Institute projects, four areas of investigation are carried out. These are: Tissue Culture, for the study of insect pathogens *in vitro;* Cell Biology, for the identification of normal cellular development and its alteration by control agents; Immunochemistry, for identification and characterization of pathogens and their constituents; and Biological Systems Analysis, for modelling and analysis of the underlying biological systems, assistance in experimental design, and methodology for interpretation and integration of results. In addition to significant individual contributions, these projects have strong ties across the Institute's research program.

FP-20 INSECT PATHOGENS *IN VITRO*

PROJECT STAFF:

S.S. Sohi (Project Leader), G. Caputo, B. Cook

OBJECTIVES: *To develop and apply insect tissue culture methodology for the* in vitro *investigation of insect pathogens with a view to enhancing their effectiveness in the management of forest insect pests.*

ACHIEVEMENTS: Over 35 continuous cell lines have been established from tissues of spruce budworm, forest tent caterpillar, whitemarked tussock moth, redheaded pine sawfly, and tobacco hornworm since the inception of the project in the early 1950s. Nuclear polyhedrosis viruses (NPV) of the original hosts have been propagated *in vitro* with these cell lines. Microsporidia have also been propagated to a more limited extent. A cell-based bioassay was developed for the *Bacillus thuringiensis (B.t.)* toxin using spruce budworm cell lines. Methods have been developed for large-scale propagation of cells and for long-term deep-freeze storage and recovery of insect cell lines. Several cell lines have been characterized by chromosome number and serological relationships. The NPV of both the whitemarked and Douglas-fir tussock moths grew very well in cell lines derived from the whitemarked tussock moth. The NPV of the spruce budworm grew very well in the homologous ovarian cell cultures. An *in vitro* bioassay was developed for *Bacillus thuringiensis* delta-endotoxin using spruce budworm cell cultures.

During 1984-85, work on developing an attached strain from the freely suspended cells of *O. leucostigma* was completed. The attached strain has been freeze-preserved and successfully revived. A $TCID_{50}$ (Tissue Culture Infectious $Dose_{50}$) bioassay was developed for the spruce budworm NPV. Ten cell lines of the western spruce budworm were tested for replication: four of these cell lines will be valuable for investigations of this virus.

PROJECTIONS: For most of 1985-86, the Project Leader will be on career development leave in Japan. During his absence, work will be done on the replication of CfMNPV.

FP-21 CELLULAR INTERACTIONS

PROJECT STAFF:

J. Percy (Project Leader), J.A. MacDonald, D. Nicholson

OBJECTIVES: *To investigate the differentiation of tissues and cells involved in the production of normal developmental patterns in insect embryos and larvae; as well as examining elaboration and transport of biosynthesized biologically active compounds or the transport of exogenous insect control agents.*

ACHIEVEMENTS: The production and transport of pheromones have been determined at the cellular and subcellular levels in several insect species. Such studies also identified more general mechanisms of transport of biologically active materials through cells and insect cuticle. Cooperative research with other projects has resulted in determination of the development and structure of a microsporidian infecting the larch sawfly, confirmation of the replication of the Douglas-fir tussock moth nuclear polyhedrosis virus (NPV) in an established cell line, and development of techniques for the study of virus replication in other cell lines. Studies have been completed on the ultrastructure of the pheromone gland of the forest tent caterpillar, the mode of action of-*B.t.* on gut cells, the presence and replication of tussock moth virus in cell lines, on the ultrastructure of wax gland cells in larvae of *Eriocampa ovata* and the chemical analysis of the secretion, and on the ultrastructural effect of nonylphenol on duckweed. During 1983-84 the Project Leader was on Development Leave at the University of Texas, Austin, Texas.

During 1984-85, the ultrastructural survey of exocrine glandular areas in the terminal abdominal segments of several species of Lepidoptera was completed. The effect of an ingested IGR on development of cuticle of sixth-instar spruce budworm larvae was determined. The project was reviewed on the return of the Project Leader and changes were recommended. These changes are reflected in the new Project Objectives.

PROJECTIONS: During 1985-86, less emphasis will be placed on the examination of tissues modified for the production of specialized compounds, and more upon the examination of tissue and cell modifications during normal development and differentiation of insect embryos and larvae.

FP-22 IMMUNOCHEMISTRY

PROJECT STAFF:

Project Leader (Vacant), B. Mathieson

OBJECTIVES: *To develop and apply immunochemical and serological techniques to the identification and characterization of microbes and insect cell cultures.*

ACHIEVEMENTS: Serological studies at the Institute have been closely allied to other biological control projects for the past 25 years. A large number of *Bacillus thuringiensis (B.t.)* strains and isolates were identified and characterized, contributing to a fuller understanding of taxonomic relationships. Serological techniques were also applied to the identification of FPMI cell lines, to identification and characterization of spruce budworm viruses, and to identification of ceratoulmin and *Gremmeniella abietina*. The Project Leader retired in 1982: since then, technical support has been provided to other FPMI projects.

PROJECTIONS: The position of Project Leader has been staffed and will be filled early in the year. The emphasis of the project will change from serology to immunology and immunochemistry.

FP-23 BIOLOGICAL SYSTEMS ANALYSIS

PROJECT STAFF:

R.A. Fleming (Project Leader)

OBJECTIVES: *To develop original research in systems analysis contributing to the alleviation of forest pest management problems, and to collaborate with other researchers interested in applying systems analysis in work related to pest management.*

ACHIEVEMENTS: This project was established in 1980 with the goal of using systems analysis to help solve forest pest management problems. Since its inception, the project has developed spruce budworm-fungal pathogen models; contributed a systems analysis perspective in the experimental design of a study to determine the environmental impact of spray drift; and developed methods for using survey data to

describe short-term spruce budworm behavior on a broad geographic basis.

During 1984-85, collaborative work was continued on phenological modeling, the permethrin drift study, and the analysis of spruce budworm survey data. A computer program was developed that improved the procedures for estimating the parameters of the distributed delay models from fungal development data. An examination of the predictive power of the large scale simulation models developed to predict spruce budworm-forest dynamics was completed.

PROJECTIONS: Work will continue on phenological modeling and on modeling for the permethrin drift study. A collaborative effort will be undertaken with CWS and the Environmental Impact Project of FPMI to develop a regression model describing the relationship between songbird brain cholinesterase and the dosage of Zectran applied aerially.

Physiological and Genetic Mechanisms

A forest insect pest grows and develops through a complex and interrelated series of steps including larval and pupal stages, mating, and reproduction. As knowledge of the physiological and genetic mechanisms associated with such development become better understood, so do the opportunities to identify critical stages that can be manipulated to control economically important insect pests. The Institute program in this area includes research into the physiological mechanisms associated with normal growth and development, the physiological and behavioral aspects of insect mating and reproductive behavior, and the dynamics of insect population genetics. The possibility of manipulating these mechanisms, through chemical or other means, to the detriment of insect survival within a generation, and from one generation to the next arises from this research.

The research into these areas leads directly to the screening of candidate insect growth regulators and pheromones that have potential for use and the development of methods for their use. Genetic research not only identifies the stages of reproduction susceptible to manipulation, but also contributes significantly to the understanding of population dynamics and how it is affected by the application of control agents, whether they are biological or chemical.

FP-30 PHEROMONES

PROJECT STAFF:

G.G. Grant (Project Leader), D. Frech, L. MacDonald

OBJECTIVES: *To advance the use of sex pheromones and related behavior modifying chemicals for the management and monitoring of forest insect pests by providing the requisite knowledge on their chemical identification, behavioral function, and practical application.*

ACHIEVEMENTS: Since its initiation in 1967, the project has contributed to the chemical identification of five pheromones of major pest species and found attractants for another 12 species, five of which are serious pests. The oak leaf shredder attractant was successfully incorporated into a post-spray monitoring system for a semi-operational spray trial in a cooperative study. Sex pheromones were successfully applied in small-scale mating disruption trials against feral populations of six species. A bioluminescent assay was developed for measuring low levels of aldehyde sex pheromones, including that of the spruce budworm.

During 1984-85, optimum pheromone blends were identified for *Eucosoma gloriola* and *Rhyacionia* species. A second component of the spruce coneworm pheromone was identified and field-tested. Screening of candidate secondary pheromone components for the spruce budmoth continued. A preliminary field screening test identified several candidate compounds for *Pseudexentera cressoniana*. Data were collected on male and female spruce seedmoth emergence from cones, intensity and timing of moth flight, cone damage and trap catches. Improvements were made in the specificity of an effective trap lure for the oak leaf shredder.

PROJECTIONS: During 1985-86, the project will concentrate on completion of pheromone identifications for *Dioryctria reniculelloides* and *Zeiraphera canadensis*. New identification work will commence on two cone pests - *Eucosoma tocullionana* and *E. monitorana*. The pheromone of the white pine weevil will be evaluated for its usefulness as a monitoring and post-spray survey tool. A laboratory study of the physical and chemical stimuli that control copulatory behavior of the spruce budworm and whitemarked tussock moth will continue.

FP-31 INSECT GROWTH REGULATORS

PROJECT STAFF:
A. Retnakaran (Project Leader), L.F. Smith, W. Tomkins

OBJECTIVES: *To evaluate and develop the rational use of insect growth regulators for the management of insect pests of the forest by studying the morphological, physiological and biochemical effects of various compounds that adversely interfere with moulting and metamorphosis in forest and model insects.*

ACHIEVEMENTS: This project has been investigating such alternative means of forest insect control as chemosterilants, radiation, and hormone analogs since 1968. Some of the successes have been control of the spruce budworm by the moult inhibitor CGA-112913, control of the forest tent caterpillar and oak leaf shredder by Dimilin, and control of the hemlock looper by the hormone analog ZR-515. Studies have also been done on *B.t.* induced feeding inhibition, use of juvenile hormone analogs to increase entomopathogenic virus propogation, and juvenile hormone effects on the Oleander hawkmoth as a model system for testing anti-juvenile hormone compounds.

During 1984-85, chitin was purified for use in synthesizing 14C-labelled oligosaccharide precursors. Investigations were completed on the JH level in the Oleander hawkmoth and the effect of precocene on the ultrastructure of the corpus allatum.

PROJECTIONS: Various new IGRs will be assayed in the lab and greenhouse. Field trials will be conducted with Diflubenzuron against the hemlock looper in Newfoundland. Studies on juvenile hormone analog-induced changes in water, protein, RNA, DNA, and lipid content in the 6th-instar budworm will be completed. Investigations will continue on the action of benzoylphenol urea inhibition of chitin biosynthesis.

FP-32 GENETIC APPROACHES

PROJECT STAFF:

In abeyance

OBJECTIVES: *To analyze the genetic components of insect reproduction, and investigate methods for manipulating pest abundance by genetic means.*

ACHIEVEMENTS: Since the project was initiated in 1972, chromosome numbers and sex determining mechanisms have been determined for more than 100 species of Lepidoptera. These mechanisms have provided a clearer understanding of the genetic complement of this group of insects. Genetic studies, carried out in collaboration with staff at GLFRC, concentrated on the *Choristoneura* group and included analyses of chromosome relationships in seven species and their hybrids. The use of sterility to reduce population levels has been intensively investigated, with basic studies being carried out on mechanisms for inducing sterility, effects on treated insects, and reduction in population fertility resulting from introduction of sterile adults. The dispersal of released adult males was determined using pheromone attractants. Results to date indicate that the potential of this method lies with low-level isolated populations rather than large-scale epidemics.

This project was placed in abeyance in 1980 after the move of the project leader into a management position.

PROJECTIONS: Reactivation of the genetics project at the Institute will depend on availability of Person Year resources. The direction of the research is dependent on the type of genetics input required by other Institute projects in biological control.

Pesticide Toxicology and Efficacy

A wide variety of forest insect pests inflict severe damage on Canadian forests each year. The best estimates currently available suggest that the average loss in wood volume caused by the activities of our major forest insect pests approaches or exceeds some 63 million m^3 per annum. In addition, competition from undesirable tree species, grasses, and weeds often impedes the establishment, survival, and growth of desired crop species by as much as 50%. Losses of this dimension cannot be tolerated if Canada is to meet wood production goals accepted by the Canadian Council of Resource and Environment Ministers for the year 2000, or if we are to maintain Canada's share of the foreign market in wood and wood products, which is so vital to our national economy. Such losses can be prevented or at least reduced substantially by the judicious use of chemical pesticides. Most chemical insecticides and herbicides, however, are developed by the pesticide industry first for the agricultural use market, which is very large and stable compared to the forestry use market. Before such materials can be registered and used for forestry purposes, their efficacy against forest insect pests and unwanted vegetation must be determined and dosage rates that will balance efficacy and acceptable environmental impact must be established.

To help ensure that forest managers have a range of effective insecticide and herbicide alternatives available for their use, the Institute maintains a continuing program that screens new products and modifies formulations of existing ones, to determine toxicity against a range of target pests. Those pesticides that appear to have potential for forestry use are tested in a series of field efficacy trials to establish actual use potential, required dosage rates, and use patterns after full consideration has been given to the biology of target pests and host species. The data generated by this program become essential components of the data package that is eventually submitted in support of registration of these pesticides for forestry use under the Pest Control Products Act. They also form the basis of control recommendations to forest managers.

FP-50 INSECTICIDE TOXICOLOGY

PROJECT STAFF:

B.V. Helson (Project Leader), D. Comba, J. McFarlane

OBJECTIVES: *To determine the toxicological properties of insecticides and their formulations, and other chemicals, on forest insect pests and selected nontarget organisms and for those that show potential for use, to provide projected dosage levels and use patterns for further field testing.*

ACHIEVEMENTS: The toxicological properties of large numbers of chemical insecticides to spruce budworm larvae and numerous other forest insect pests have been investigated since the inception of this project in 1965. Fenitrothion, aminocarb, acephate, and permethrin, which are all now registered for forestry use, were originally identified through this program. Sumithion 20 Flowable, which was tested by this project, is now in the registration process. Studies were initiated to identify potentially effective insecticides for control of the spruce budmoth, to determine the relative toxicity of forestry insecticides to wild pollinators, and to assess the potential impact of permethrin drift deposits on aquatic insects.

During 1984-85, several insecticides were tested against first-instar spruce budmoth to determine their contact toxicity, toxicity as foliar deposits, and residual toxicity. Permethrin and mexacarbate were recommended for further field testing. Studies were initiated to determine the toxicity of certain insecticides and new formulations to eastern hemlock looper, jack pine budworm, black army cutworm, and white pine weevil. Further tests were conducted to determine the relative toxicity of forestry insecticides to several wild pollinators. The impacts of permethrin drift deposits from one mistblower and one aerial application were assessed with a modified bioassay technique using mosquito larvae.

PROJECTIONS: During 1985-86, studies on the toxicological properties of Zectran, Larvin, and AC217-300 to spruce budworm will continue. Studies with Sumithion 20 Flowable will be completed. Research on the toxicity of insecticides to the spruce budmoth will also be completed. Investigations on the toxicities of selected new insecticides and formulations to eastern hemlock looper and jack pine budworm will

be continued and expanded. The study on the use of bioassays with mosquito larvae to assess the impact of permethrin drift will be completed. A study will be established to determine the effects of droplet size on the contact toxicity of insecticides to spruce budworm larvae.

FP-51 INSECTICIDE FIELD EFFICACY

PROJECT STAFF:

B.L. Cadogan (Project Leader), P. Ebling, C. Nystrom, L. Pollock, B. Zylstra

OBJECTIVES: *To develop suitable methodology and data to assess the efficacy of insecticides, formulations, and pest control strategies as required for the management of forest insect pests.*

ACHIEVEMENTS: Since its inception in the mid-1950s, this project has been primarily concerned with field efficacy testing of insecticides with potential for forestry use. Data arising from this project have been used to assess the efficacy of virtually all insecticides currently registered for forestry use in Canada today. Improved methods of applying these materials in a manner that optimizes effectiveness while minimizing environmental impact have been developed. Semi-permanent research facilities have been established at Thessalon for conducting aerial application research. Four types of spray dispersal equipment were examined and a technique was developed to assess sprays in conifers.

During 1984-85, Zectran UCZF19 was sprayed in both water and oil: the results show that this insecticide is efficacious. A new Sumithion flowable formulation was field-tested in New Brunswick. The new formulation was shown to be as effective as Sumithion Technical. A cooperative study with the OMNR continued to collect field data on deposit patterns from different nozzle configurations.

PROJECTION: Three insecticides (Futura, Matacil 180F, and Sumithion 20F) will be field-tested to evaluate their efficacies against jack pine budworm. The cooperative study on deposit characteristics from different spray dispersal systems will continue with OMNR. Research will continue on the evaluation of a sampling apparatus that collects deposit on the midcrown of conifers.

FP-52 PLANTATION PEST MANAGEMENT

PROJECT STAFF:

J. Turgeon (Project Leader), P. de Groot (Study Leader), N. Charlebois, A. Obarymskyj

OBJECTIVES: *To develop adequate protection strategies for insect pests of coniferous plantations grown for seed and lumber production.*

ACHIEVEMENTS: Since 1982, this project has been involved in collecting biological, ecological, and behavioral information on the spruce budmoth, a 'new' pest of white spruce plantations. Insecticides have also been screened for the control of this insect. Several protection strategies were identified from these studies. The project has also been actively involved in a cooperative project to establish buffer zones around bodies of water to limit the impact on aquatic arthropods of permethrin applications.

During 1984-85, most of the ecological studies on the spruce budmoth were satisfactorily completed. The screening of insecticides against this insect continued: an aerial application of insecticides was conducted at larval emergence in plantations under study. The project to establish buffer zones around water bodies was also continued. The study leader of the Protection Strategies and Techniques study was away on educational leave for most of this year.

PROJECTIONS: Studies on the relative toxicity and persistence of permethrin, Zectran, Matacil, fenitrothion, methomyl, and on identification of the spruce budmoth pheromone will be completed. During 1985-86, this project will become actively involved in a long term study to develop pest management strategies for insects that affect cone and seed production in seed orchards and in seed production areas. Studies will also be initiated to provide basic information on pests that affect seed and cone production, and on crop dynamics of the species affected.

FP-54 HERBICIDES DEVELOPMENT AND USE

PROJECT STAFF:

P. Reynolds (Project Leader), R. Prasad (Study Leader), J. Feng (Study Leader), T. MacKay, D. Travnick, J. Yoo

OBJECTIVES: *To develop data required for the registration of herbicides for forestry use in Canada and to develop new and improved use strategies for forestry herbicides that provide maximum crop tree growth response with minimal environmental impact.*

ACHIEVEMENTS: The FPMI herbicides project was initiated in 1981 in response to concerns that had been expressed by forest managers about the scarcity of vegetation management tools. A comprehensive protocol has been established for the evaluation of new herbicides under laboratory, greenhouse, and field conditions. A greenhouse, dedicated to herbicide research, was constructed and equipped with a modern automated spray chamber.

During 1984-85, cooperative projects with DuPont Canada continued with aerial soil-applied and foliar-applied Velpar trials on J.D. Irving lands in New Brunswick. The Carnation Creek Watershed, in B.C., was aerially treated with Roundup as part of a study to clarify remaining federal concerns relating to the registration of glyphosate as a conifer release herbicide. Major cooperative herbicide (glyphosate) drift trials were carried out with the Spray Cloud Behavior project near Terrace, B.C. Weed and crop tree phytotoxicity studies were carried out in the greenhouse with materials provided by OMNR and the B.C. Forest Service. Analysis of Velpar soil samples collected in New Brunswick in 1984 and Ontario in 1983 was completed.

PROJECTIONS: During 1985-86, herbicide spray operations for the proposed Skeena River Garlon trials will be completed. One-year vegetation assessments for Velpar and the Carnation Creek Watershed glyphosate trial will be conducted. Environmental impact studies for the proposed Skeena River Garlon trials will be conducted in cooperation with the Environmental Impact Project. Greenhouse spray chamber and small plot herbicide trials will continue. Glyphosate residue analyses will be completed for samples collected in the Carnation Creek and Skeena River trials. Analysis of triclopyr residue samples from the proposed Skeena River trials will be initiated.

Application Technology

The ultimate goal in the operational application of any pesticide by whatever application method is to assure that only the essential required amount of the pesticide is emitted, and that as much of the emitted material as possible reaches the intended target in a form that optimizes its effectiveness against the target pest. If this goal is achieved, drift beyond the target area is minimized and the effectiveness of the pesticide against its intended target is maximized.

A great number of factors affect achievement of this ultimate goal. For example, the physico-chemical characteristics of liquid sprays affect the production, size, and evaporation of the spray droplets. Dispersal system design, nozzle type, pressure, flow rate of the emission system, and speed of the vehicle carrying the emission system also influence the droplet pattern produced. Meteorological conditions during application affect the movement of the spray cloud, evaporation of the droplets, and penetration into and impaction on the forest canopy.

A thorough understanding of all of these factors and their interactions is essential if pesticides are to be applied in the most economical, efficacious, and environmentally acceptable manner. Therefore, research into all of these areas is an important aspect of the Institute's overall R & D program.

FP-60 DISPERSAL SYSTEMS

PROJECT STAFF:

Vacant

OBJECTIVES: *To test and assess new or modified spray emission systems on aircraft and ground spray equipment for improved pesticide applications.*

ACHIEVEMENTS: Research carried out during the 1960s on the basic principles of ultra-low volume application technology resulted in the introduction of incremental application technology of wide swath spraying using multi-engine aircraft, full span above-the-wing boom and open nozzle spray system, and electronic guidance systems for accurate swath alignment. A simple, compact, efficient, folding, flat-plate sampling unit was developed to ensure rapid retrieval of spray deposit data to provide reliable cumulative deposit results from both research and operational sprays. A compact emergence box was developed for the collection of 2nd- and early 3rd-instar budworm larvae from whole branch samples.

This position remained vacant during 1984-85 and research related to dispersal systems testing was largely carried out by other projects. Such research included investigations with through valve boom (TVB), microfoil, raindrop, micronair or conventional atomization systems with herbicides and insecticides.

PROJECTIONS: Steps have been taken to initiate staffing of this position at a suitable professional level as promptly as possible.

FP-61 PESTICIDE FORMULATIONS

PROJECT STAFF:

A. Sundaram (Project Leader), J. Leung

OBJECTIVES: *To assess and/or modify the physical and chemical properties of pesticide formulations in order to improve upon stability, handling, dispersal and deposition characteristics required to maximize efficacy and minimize environmental impact.*

ACHIEVEMENTS: This project was initiated in 1980. The project has investigated the physical properties of various pesticide formulations, tank mixes, and component materials to determine their viscosity, density, surface tension, evaporation rate, and the influence of these factors on emission characteristics through a range of emission systems. A wind tunnel - spray chamber was constructed to study the influence of formulation ingredients on spray droplet spectra, foliar impaction and retention characteristics. Actual deposition and distribution of droplets of various sizes on coniferous foliage were assessed in the field using a new formulation that provided in-flight microencapsulation of droplets. Project staff were involved in the FPMI/CFS Action Plan to find replacement emulsifiers (to Atlox 3409F) for fenitrothion and aminocarb flowable insecticides.

During 1984-85, the project carried out an investigation of the degree of adhesion of spray droplets of one *B.t.* formulation with and without stickers. The influence of viscosity, volatility, and distillation points of spray diluents on droplet spectra and deposit characteristics were investigated for a wide range of petroleum and vegetable oils used in pesticide sprays. Two gravimetric methods for studying comparative volatilities were developed - one for non-aqueous pesticide formulations and spray diluents and one for water based formulations and adjuvants. The project also participated with other projects and outside agencies in the areas of application technology, spray deposit assessment, efficacy and environmental effects.

PROJECTIONS: During 1985-86, the degree of adhesion of spray droplets of one *B.t.* and one fenitrothion formulation with and without stickers at a low relative humidity will be investigated. The role of relative humidity on droplet

adhesion characteristics of three *B.t.* formulations will be determined. A method will be developed to determine the relationship between droplet size, retention and spreading characteristics of two herbicide formulations.

FP-62 SPRAY CLOUD BEHAVIOR

PROJECT STAFF:

N. Payne (Project Leader), J. Beveridge

OBJECTIVES: *To investigate and quantify the effects of physical parameters on spray cloud dispersal and deposition with the aim of increasing efficacy and reducing off-target deposit from, and cost of, forestry pesticide applications.*

ACHIEVEMENTS: The spray cloud behavior project was formed in 1970 to carry out research to determine the meteorological conditions that would optimize spray deposition at the target. The project worked towards developing guidelines for spray operators to use in evaluation of meteorological conditions used for spray applications. The project existed without a project leader from 1978-1983. With the arrival of the new project leader in 1983, the project was revised and the scope of the project was broadened. Improvements were made to droplet sampling and meteorological equipment.

During 1984-85, an experiment to quantify aerosol, foliar, water, and ground deposit from Roundup applications with various atomizers was carried out in cooperation with the Herbicides Development and Use Project. The results are currently being analyzed by the Herbicides Chemical Accountability Study. The project also participated in the permethrin drift study.

PROJECTIONS: During 1985-86, field experiments will be carried out to measure droplet impaction efficiencies in turbulent air-flow and to calibrate droplet collectors. The dispersal of ULV spray clouds will be investigated in boundary layers with different stabilities and at different windspeeds. The cooperative study with the Herbicides Project on optimum droplet sizes for herbicide efficacy will continue.

Environmental Concerns

Before a pesticide can be used in Canada it must be registered under the Pest Control Products Act, which is administered by Agriculture Canada. Under the terms of this Act, a pesticide must be proved effective and its use must not have a significant, adverse impact on environmental quality or on human health. To have such materials registered for forestry use in Canada and to develop the most appropriate use patterns for them, it is essential that we have an adequate understanding of their impact on non-target, naturally occurring species in the forest environment, and of their persistence, mobility, and ultimate fate in that environment. While such knowledge is essential for registration purposes, it is just as essential in adequately addressing public concerns relating to the use of these forest management tools.

A significant portion of the Institute's technical expertise and resources are directed toward determination of the effect of pesticides (chemical and biological) on non-target avian, terrestrial, and aquatic organisms in the forest environment and to elucidation of the occurrence and fate of these materials, and their breakdown products in foliage, soil, litter, water, and bottom sediment after application.

FP-70 ENVIRONMENTAL IMPACT

PROJECT STAFF:

P.D. Kingsbury (Project Leader), S.B. Holmes, D.P. Kreutzweiser, B.B. McLeod, R. Millikin, K. Mortensen

OBJECTIVES: *To develop necessary experimental methods and carry out field and laboratory studies to determine potential environmental impacts of forest pesticides on forest ecosystems and to develop and recommend pest management strategies and pesticide use patterns to minimize these impacts under operational conditions.*

ACHIEVEMENTS: Over the past decade, this project has worked with other FPMI and CFS projects to evaluate the environmental effects of numerous chemical and biological insecticides and has re-evaluated operational materials that were registered before current stringent registration requirements came into effect. A great deal of effort has gone into developing methodologies for monitoring the effects of forest pest control operations and transferring these techniques to regional and provincial agencies. More recently, emphasis has shifted to in-depth studies designed to examine in greater detail the nature and degree of risk, exposure and response of forest communities to pesticide applications.

During 1984-85, data collection continued on forest songbird and brook trout studies in the Icewater Creek research area. Taxonomic and life history evaluations of aquatic insects from Icewater Creek continued, as did wild pollinator activity, baseline data and topical application toxicity testing on selected pollinators. An extensive study on forest songbird brain cholinesterase responses to mexacarbate was done in cooperation with the CWS. Spray chamber studies with a caged bird species and fenitrothion were also carried out jointly with the CWS. Aquatic invertebrate drift responses to experimental applications of the herbicide glyphosate were evaluated as part of a multi-agency study in the Carnation Creek watershed in B.C. Aquatic impacts were evaluated from the cooperative permethrin drift study.

PROJECTIONS: Aerial application of pesticide to the Icewater Creek research area will be initiated in 1985: responses will be evaluated through 1985-86. The impact of mexacarbate on the aquatic fauna within a treated New

Brunswick watershed will be evaluated. The short-term impact of the herbicide triclopyr on aquatic organisms in the Skeena River of B.C. will be investigated to generate data required to support the registration of this material for use in Canadian forests. Laboratory toxicity studies with a variety of forestry insecticides against four bee species will be completed.

FP-71 CHEMICAL ACCOUNTABILITY

PROJECT STAFF:

K.M.S. Sundaram (Project Leader), C. Feng, J. Broks, R. Nott

OBJECTIVES: *To develop analytical methodology and to determine the environmental distribution, degradation, dynamics, persistence, and metabolic fate of forest insect control products in order to help in the evaluation of their benefits and potential risks to the ecosystem.*

ACHIEVEMENTS: The research of this project has provided sensitive analytical methods to identify and quantify various pest control chemicals and their metabolites used in forest spray programs and also their environmental persistence, mobility, cycling, toxicity and ultimate fate in different components of the forest ecosystem. Data generated by this project have been used in registration packages for such products as fenitrothion, trichlorfon, acephate, carbaryl and aminocarb insecticides. New spray mixes of aminocarb and fenitrothion containing the Triton X-series of emulsifiers were developed and field tested. The project has participated in the cooperative permethrin drift study, and developed model ecosystems to study the fate of pesticides in aquatic environments.

During 1984-85, a new microcolumn cleanup technique was developed and used successfully to cleanup mexacarbate and permethrin samples from forestry substrates. Quantitative thin-layer chromatographic techniques were developed to separate, identify and quantify mexacarbate from environmental samples. A procedure was developed to study the mobility, degradation, and fate of 14C-mexacarbate in forest soil profiles. Distribution, persistence, and fate of aqueous and oil-based mexacarbate in a forest ecosystem in New Brunswick were evaluated. Involvement continued in the Check Sample program under the auspices of the Federal Interdepartmental Committee on Pesticides.

PROJECTIONS: During 1985-86, the project will continue to develop techniques for the analysis of pesticide residues in various forestry substrates. Zectran will be tested in the field to evaluate its fate in the aquatic environments of New Brunswick forests. The project will participate in the spray trial at Icewater Creek by studying canopy penetration and exposure levels of fenitrothion to songbirds, pollinators and insects.

Complementary Services

A wide range of services that can produce the insect species, pathogens, and plant material required for laboratory research and field testing are essential to the conduct of research at the Institute. Insects provided by the Insect Production section are used in a variety of laboratory experiment and testing programs, for production of insect viruses for field testing and operational use, and for distribution to a number of cooperators within and outside the CFS. The Pathogen Production section produces viruses for testing, and indeed, is presently the sole source for the two insect viruses registered for forestry use in Canada. In the Plant Production section are grown a variety of plant species required for insect food and for screening of biological and chemical insecticides, as well as representative desirable and undesirable species for use in screening of herbicides with potential for use in Canadian forestry.

FP-40-1 INSECT PRODUCTION

PROJECT STAFF:

D. Grisdale (Study Leader), K. Barratt, C. Budau, L. Harwood, H. Lauzon, A. McMorran, S. White

OBJECTIVES: *To develop and carry out insect rearing methods that will provide the numbers and varieties of insects required by Institute research projects.*

ACHIEVEMENTS: Since 1963, the insect rearing capability of this section has developed into the largest of its kind in Canada, supplying insects not only to FPMI but also to various CFS establishments, universities and other research centres in Canada and the U.S. About 10,000 litres of artificial diet are prepared and dispensed annually to support the rearing done at FPMI.

During 1984-85, seventeen insect species were reared and over 5 million insects were produced. Large numbers of spruce budworm (about 3 million) were produced and shipped to cooperating agencies. A non-diapause strain of the western spruce budworm was used exclusively to produce virus during the winter pathogen production program. Efforts to establish a black army cutworm laboratory culture achieved some success: several thousand larvae were reared for virus and insecticide tests. Second-instar jack pine budworm were forced from foliage and a laboratory culture was started.

PROJECTIONS: Production will continue at a high level, with types and numbers reared depending on demand. Rearing techniques for the black army cutworm and jack pine budworm will be improved.

FP-40-2 PATHOGEN PRODUCTION

PROJECT STAFF:

J. McPhee (Study Leader), H. Wigney

OBJECTIVES: *To develop, adapt, modify and apply sophisticated methodology to mass production of viruses and protozoa for subsequent use in the regulation of forest insect pests.*

ACHIEVEMENTS: To date, pathogen production has been devoted exclusively to insect viruses. Material has been supplied for field trials conducted by the Viral Pathogens Project since 1970. Viruses produced in the laboratory include spruce budworm entomopoxvirus (EPV), nuclear polyhedrosis virus (NPV) granulosis virus (GV), Douglas-fir tussock moth NPV, forest tent caterpillar NPV, Bruce spanworm NPV, and winter moth NPV. Virtuss (NPV for control of Douglas-fir tussock moth) has been stockpiled since 1977 to ensure that there will be enough material to treat the next outbreak in B.C. Formulation of viral material in an emulsifiable oil was found to be a convenient method of distribution to clients.

During 1984-85, production of Virtuss and spruce budworm NPV continued. Lecontvirus and Sertifervirus were produced: enough Lecontvirus to treat about 16,000 ha and enough Sertifervirus to treat about 160 ha were produced. Small amounts of NPVs of Swaine's jack pine sawfly, balsam fir sawfly and pine tussock moth were produced. Lecontvirus was distributed to staff in two OMNR districts. Lecontvirus stored for 1 and 2 years in emulsifiable oil was field-tested, and it was found that there was a major loss of activity in 1 year and almost a total loss in 2 years: an expiry date will now be marked on Lecontvirus labels.

PROJECTIONS: Virus production will continue to meet Institute research needs and requests from clients. Alternatives to emulsifiable oil as a carrier for viral insecticides distributed to clients will be investigated.

FP-40-4 GREENHOUSE & ANIMAL SERVICES

PROJECT STAFF:

D. Buckley (Study Leader), N. Lautenslager

OBJECTIVES: *To adapt, develop, extend and apply sophisticated methodology in plant production and animal rearing that will provide, as required, material for use in the Institute's research programs.*

ACHIEVEMENTS: Greenhouse facilities have been established that can provide a broad range of plant material for use in bioassays, insect production, single tree experiments and application technology development. Flushed potted trees

are available nearly year round enabling screening activities and host-insect research to be carried out on a continuous basis. The animal facility maintains small mammals required for the Serology and Viral Biochemistry studies.

During 1984-85, a variety of plants and potted trees were produced for use in screening or research studies throughout the Institute. Approximately 6 kg of mulberry foliage are provided weekly and 6 oleander and 6 tomato plants are produced at 6 week intervals as substrates for oviposition. About 2,200 potted conifers, 30-35 cm in height, were supplied to researchers. Small amounts of alfalfa, beans, potato, and wheat were grown for insect food and small experiments.

PROJECTIONS: Production will be maintained, culture methods will be improved and the inventory of plant material will be increased.

Information and Technical Services

No research can be considered complete until the results have been transferred effectively to potential users. FPMI is closely associated with other federal departments, other governments, private industry, and the Canadian public. It is therefore essential that results from the FPMI research program reach the publics for which they are intended. The Scientific Editing and Information Services Unit is responsible for: developing and modifying the packaging and format of reports to meet changing demand; providing an editorial capability in both official languages; preparing and issuing regularly issued publications according to schedule; and, responding to requests for information.

The Information and Technical Services Unit at the Institute provides these and other services, contributing in a significant manner to the overall program at FPMI.

FP-93 SCIENTIFIC EDITING AND INFORMATION SERVICES

PROJECT STAFF:

K.B. Griffiths (Project Leader), B. Arsenault, S.A. Stitt

OBJECTIVES: *To publish and disseminate scientific and technical information that arises from the Institute's program in the most appropriate form to facilitate the transfer of forest pest management science and technology to user groups.*

ACHIEVEMENTS: This project was initiated in 1980, and since then has provided liaison, technology transfer, editorial, and information services to the Institute. When the original project leader left in 1983, the project was reviewed and reorganized and the emphasis was put on the scientific editing and publications functions. Since its reorganization, the project has provided editorial, graphics and information distribution functions for the Institute.

During 1984-85, the position of Bilingual Technical Editor was staffed, bringing the project up to its full capacity. Thirty-two journal papers, 6 information reports, 4 issues of the Newsletter, 3 Technical Notes, the annual Program Review and various miscellaneous papers were published through the project. During the year, 2100 journal reprints, 2000 information reports, 535 Technical Notes and 50 French publications were distributed. The format of the quarterly Newsletter was considerably enhanced and a Newsletter Committee was set up to establish an editorial policy for the Newsletter and to assist in the collection of articles. Most current information reports, all Technical Notes and most Newsletters are now available in French.

PROJECTIONS: During 1985-86, the project will become involved, to a small degree, with public information. A computer bibliography, with abstracts, of all current FPMI publications will be created. Involvement will continue on the FPMI audiovisual, and a high level of scientific editing and information services will be maintained.

Administrative and Common Support Services

Administrative Support Services (material management, records management, office services, fleet management, operation and maintenance of physical plant) and financial services are provided to both the Forest Pest Management Institute and the Great Lakes Forest Research Centre through one administrative unit carried on the Great Lakes Forest Research Centre allocation but responsible to the Directors of both establishments. Integration of these services has been total since 1978. Some economies in staff have resulted. These integrated services have functioned in a highly satisfactory manner since their inception, and are considered the most appropriate organizational option for sister establishments of the same service sharing the same physical facility.

Integrated joint library services are provided to both establishments in a similar fashion with permanent library staff carried on the Great Lakes Forest Research Centre allocation. This, too, has resulted in some economies in both staff and library space with the added advantage that library equipment and other facilities do not have to be duplicated.

As opportunities present themselves in the future, the desirability of further integration of common support services will be investigated thoroughly with the Great Lakes Forest Research Centre.

FP-97 ADMINISTRATION, FINANCIAL AND ENGINEERING SERVICES

PROJECT STAFF:

(GLFRC)

OBJECTIVES: *To provide effective and efficient administrative and financial services in support of FPMI's program; to provide adequate physical facilities within which the Forest Pest Management's R & D program can be carried out and to ensure that these are operated and maintained in the most efficient and effective manner.*

ACHIEVEMENTS: One administrative unit, carried on the Great Lakes Forest Research Centre (GLFRC) allocation, has served both GLFRC and FPMI since the latter was formed in 1977-78. Engineering Services were integrated in 1977 and the remainder of administrative and financial services followed in the beginning of fiscal 1978. This integrated system has served both establishments in a highly satisfactory manner to date.

During 1984-85 administrative, financial and engineering services continued to be provided in an efficient and effective manner. Word processing capability was further enhanced by the addition of a Fox 1001 stand-alone-text-entry device. The inventory of the vehicle fleet was fully computerized. The major project this year was the ongoing construction of the laboratory and administration addition to the main complex. A repair and improvement program was carried out at field stations and a new storage building was constructed at the Insectary.

PROJECTIONS: During 1985-86, computerization of administrative services will be continued, the word processing unit will be upgraded, and financial services will continue to function in an effective manner. It is expected that Phase II construction will be completed and occupied. Phase III of the capital building project will be initiated - this will involve major renovations to the existing main laboratory complex.

FP-94 LIBRARY SERVICES

PROJECT STAFF:

(GLFRC)

OBJECTIVES: *To develop, maintain and improve a research library commensurate with the changing requirements of the combined programs of the Great Lakes Forest Research Centre and the Forest Pest Management Institute.*

ACHIEVEMENTS: The joint library servicing FPMI and GLFRC has served both establishments well since its inception in 1978. It provides upwards of 450 periodicals and abstracting journals for staff and has an accession list of more than 8000 reference texts covering the very broad range of subjects included in the R & D program of the two establishments it serves. With the addition of a computer terminal in 1982-83 the efficiency of literature searches was increased significantly.

During 1984-85, the Library Serials Holdings List was updated and distributed; a copy was sent to the Canada Institute of Scientific and Technical Information for inclusion in the next issue of the Union List of Scientific Serials in Canadian Libraries. A collection of FMSA reports were acquired. Work continued on various aspects of planning the expansion of the library.

PROJECTIONS: During 1985-86, monitoring of computer search services will continue, with a view to acquiring accounts with OL systems and the Bibliographic Retrieval System. Involvement will continue in the expansion of the library.

Appendices

FOREST PEST MANAGEMENT INSTITUTE
EXPENDITURES 1984-85
($000s)

PROGRAM AREA	PERSON YEARS	SALARIES	OPERATIONS & MAINTENANCE	CAPITAL	TOTAL
Management	5.0	212.2	46.5	--	258.7
Finance & Administration	--	--	246.3	105.4	351.7
Physical Plant	--	--	261.3	10.3	271.6
Sci. Editing & Information	3.0	82.3	24.2	2.1	108.6
Library	--	--	52.1	--	52.1
Complementary Services	14.3	367.3	27.0	0.6	394.9
Microbial Control Agents	16.0	600.5	69.0	65.4	734.9
Biological Interactions	9.0	289.8	24.9	3.7	318.4
Physiological & Genetic Mechanisms	6.0	256.1	23.0	16.4	295.5
Pesticide Toxicology & Efficacy	18.0	631.0	150.2	73.8	855.0
Application Technology	5.0	147.1	28.2	69.2	244.5
Environmental Concerns	10.0	411.5	45.3	10.3	467.1
TOTAL:	86.3	2 997.8	998.0	357.2	4 353.0

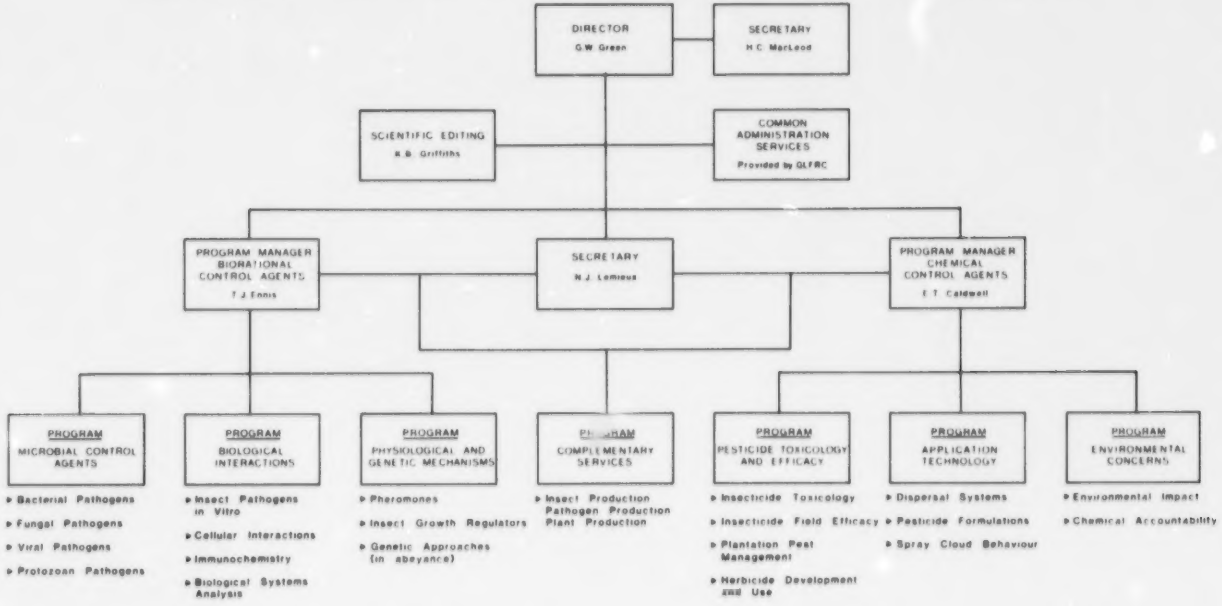
Note: The above figures do not include:

(i) $128.2 K received for SCIP (summer student salaries)
(ii) $247.1 K in PRUF contracts listed elsewhere in this Program Review

FOREST PEST MANAGEMENT INSTITUTE
RESEARCH & DEVELOPMENT CONTRACTS 1984-85

CONTRACTOR	TITLE	AMOUNT ($)	SCIENTIFIC AUTHORITY
	1. From A-Base O & M		
D. Joly University of Ottawa	Purification of the 130 K Dalton Protoxin of *B.t.*	9,990	P. Fast (FP-10)
G.M. Olah Université Laval	Conidial germination of entomophthorales in spruce budworm	4,000	D. Perry (FP-11)
	Subtotal (A-Base R & D Contracts)	13,990	
	2. PMF Contracts		
G.A. Surgeoner University of Guelph	Evaluation of insecticides used in spruce budworm control on non-target aquatic organisms utilizing a flow-through stream system	32,640	P.D. Kingsbury (FP-70)
G. Geen Simon Fraser University	Evaluation of a forestry herbicide on the ecology of juvenile salmonids in the Skeena River watershed	47,500	P.D. Kingsbury (FP-70)
J. Roder Queen's University	Production of monoclonal antibodies against components of baculoviruses	16,754	W. Kaupp (FP-13)
G.R. Stephenson and K.R. Solomon University of Guelph	Leachability, persistence and lateral movement of triclopyr (Garlon) in selected Canadian forest soils	29,304	P. Reynolds (FP-54)
D.N. Roy University of Toronto	Persistence, movement and degradation of hexazinone (Velpar) in selected Canadian forest soils	19,668	R. Prasad (FP-54)

FOREST PEST MANAGEMENT INSTITUTE - PROGRAM ORGANIZATION



FOREST PEST MANAGEMENT INSTITUTE
ORGANIZATION & STAFF LISTING
(As of 31 March, 1984)

Director	Dr. G.W. Green Secretary: H.C. MacLeod
Program Managers	Dr. T.J. Ennis Deputy Director Mr. E.T.N. Caldwell Secretary: N.J. Lemieux
Administrative Officer	M.J. Parent Great Lakes Forest Research Centre
Scientific Editing	K.B. Griffiths Editor B. Arsenault S. Stitt

RESEARCH & DEVELOPMENT PROJECTS

MICROBIAL CONTROL AGENTS

Program Manager: Dr. T.J. Ennis

Project No.	Title	Scientific Staff	Technical Staff
FP-10	Bacterial Pathogens	Dr. P.G. Fast (Project Leader) Vacant (Study Leader)	R. Milne
FP-11	Fungal Pathogens	Dr. D. Tyrrell (Project Leader) Dr. D. Perry	K. Humphries M. Welton
FP-12	Protozoan Pathogens	Dr. G.G. Wilson (Project Leader)	E. Young

Program Manager: Dr. T.J. Ennis

Project No.	Title	Scientific Staff	Technical Staff
FP-13	Viral Pathogens	Dr. J.C. Cunningham (Project Leader) Dr. B.M. Arif Dr. W.J. Kaupp P.B. Jamieson	K. Brown R. Burke B. Cunningham

BIOLOGICAL INTERACTIONS

Program Manager: Dr. T.J. Ennis

FP-20	Insect Pathogens *in vitro*	Dr. S.S. Sohi (Project Leader)	G. Caputo B. Cook
FP-21	Cellular Interactions	Dr. J. Percy (Project Leader)	J.A. MacDonald D. Nicholson
FP-22	Immunochemistry	Vacant (Project Leader)	B. Mathieson
FP-23	Biological Systems Analysis	Dr. R.A. Fleming (Project Leader)	

PHYSIOLOGICAL & GENETIC MECHANISMS

Program Manager: Dr. T.J. Ennis

FP-30	Insect Pheromones	Dr. G.G. Grant (Project Leader)	D. Frech L. MacDonald
FP-31	Insect Growth Regulators	Dr. A. Retnakaran (Project Leader)	L.F. Smith W. Tomkins
FP-32	Genetic Mechanisms	Dr. T.J. Ennis (Project in temporary abeyance)	

PESTICIDE TOXICOLOGY AND EFFICACY

Program Manager: Mr. E.T.N. Caldwell

FP-50	Insecticide Toxicology	Dr. B.V. Helson (Project Leader)	D. Comba J. McFarlane

Program Manager: Mr. E.T.N. Caldwell

Project No.	Title	Scientific Staff	Technical Staff
FP-51	Insecticide Field Efficacy	Mr. B.L. Cadogan (Project Leader)	P. Ebling C. Nystrom L. Pollock B. Zylstra
FP-52	Plantation Pest Management	Dr. J. Turgeon (Project Leader) Mr. P. deGroot	N. Charlebois A. Obarymskyj
FP-54	Herbicide Development and Use	Dr. P. Reynolds (Project Leader) Dr. R. Prasad Mr. J. Feng	D. Travnick J. Yoo

APPLICATION TECHNOLOGY

Program Manager: Mr. E.T.N. Caldwell

FP-60	Dispersal Systems	Vacant (Project Leader)	
FP-61	Pesticide Formulations	Dr. A. Sundaram (Project Leader)	J. Leung
FP-62	Spray Cloud Behavior	Dr. N. Payne (Project Leader)	J. Beveridge

ENVIRONMENTAL CONCERNS

Program Manager: Mr. E.T.N. Caldwell

FP-70	Environmental Impact	Mr. P.D. Kingsbury (Project Leader) Mr. S. Holmes	D.P. Kreutzweiser B.B. McLeod R. Millikin K. Mortensen
FP-71	Insecticide Chemical Accountability	Dr. K.M.S. Sundaram (Project Leader) Mrs. C. Feng	J. Broks R. Nott

COMPLEMENTARY SERVICES

Program Manager: Dr. T.J. Ennis
Mr. E.T.N. Caldwell

Project No.	Title	Scientific Staff	Technical Staff
FP-40-1	Insect Production	Mr. D. Grisdale (Study Leader)	K. Barratt C. Budau L. Harwood H. Lauzon A. McMorran S. White
FP-40-2	Pathogen Production	Mr. J. McPhee (Study Leader)	H. Wigney
FP-40-4	Greenhouse Services	Mr. D. Buckley (Study Leader)	N. Lautenslager

PUBLICATIONS 1984-85

The following list of publications includes only those papers published or issued during the 1984-85 fiscal year (April 1, 1984 - March 31, 1985). The material listed here includes only journal articles, book chapters, and Information Reports. Many other reports of an internal or special nature were written but, because they are not intended for general circulation, they are not listed here.

PUBLICATIONS

Arif, B.M. 1984. The entomopoxviruses. Advances Virus Res. 29: 195-213.

Arif, B.M.; Doerfler, W. 1984. Identification and localization of reiterated sequences in the *Choristoneura fumiferana* MNPV genome. EMBO J. 3: 525-529.

Arif, B.M.; Kuzio, J.; Faulkner, P.; Doerfler, W. 1984. The genome of *Choristoneura fumiferana* nuclear polyhedrosis virus: Molecular cloning and mapping of the EcoRI, BamHI, SmaI, XbaI and BglII restriction sites. Virus Res. 1: 605-614.

Arif, B.M.; Tjia, S.T.; Doerfler, W. 1985. DNA homologies between the genomes of *Choristoneura fumiferana* and *autographa californica* nuclear polyhedrosis virus. Virus Research 2: 85-94.

Cadogan, B.L.; Zylstra, B.F. 1984. An apparatus and technique for sampling aerially applied sprays in conifers. Pesticide Science 15: 417-423.

Cunningham, J.C.; deGroot, P.; McPhee, J.R. 1984. Lecontvirus: viral insecticide for control of redheaded pine sawfly, *Neodiprion lecontei*. Can. For. Serv., Forest Pest Management Institute, Tech. Note No. 2, 5 p.

Fast, P.G. 1983. *Bacillus thuringiensis* parasporal toxin: aspects of chemistry and mode of action. Toxicon, suppl. 3: 123-125.

Fleming, R.A.; Shoemaker, C.A.; Stedinger, J.R. 1984. An assessment of the impact of large scale spraying operations on the regional dynamics of spruce budworm (Lepidoptera: Tortricidae) populations. Can. Ent. 116: 633-644.

Grant, G.G.; Slessor, K.N. 1983. Sex pheromone of the maple leaf roller, *Cenopis acerivorana* (Lepidoptera; Tortricidae). Can. Ent. 115: 189-194.

Gray, T.G.; Slessor, K.N.; Sheperd, R.F.; Grant, G.G.; Manville, J.F. 1984. European pine shoot moth, *Ryhacionia brioliana* (Lepidoptera: Tortricidae): identification of additional pheromone components resulting in an improved lure. Can. Ent. 116: 1525-32.

Grisdale, D.G. 1984. Forest tent caterpillar. pp. 369-378 *in* Handbook of Insect Rearing vol. 2 (P. Singh and R.F. Moore, eds), Elsevier Amsterdam.

Grisdale, D.G. 1984. Hemlock looper, pp. 345-353 *in* Handbook of Insect Rearing vol. 2 (P. Singh and R.F. Moore, eds). Elsevier, Amsterdam.

Holmes, S.B.; Kingsbury, P.D.; Mamarbachi, G.; Mathieu, P. 1984. Distribution of fenitrothion residues in brook trout *(Salvalinus fontinalis)* and lake trout *(S. namaycush)* tissues following aerial applications to Lac Ste-Anne, Quebec. Bull. Environ. Contam. Toxicol. 33: 468-475.

Luthy, P.; Arif, B. 1985. Designing microorganisms for insect control. Bioassays 2: 22-25.

Percy, J.; Wacker, K.; Kalthoff, K. 1985. Pattern discontinuities in an apparent mutant, spontaneous double abdomen of *Chironomus* sp. Texas J. Science (in press).

Retnakaran, A. 1985. Evaluating spray data using Abbott's formula. Can. For. Serv., For. Pest Manage. Inst. Tech. Note 3, 2 pp.

Retnakaran, A.; Ennis, T.J. 1985. *In vitro* mutagenicity testing of a potent, new benzoyl urea insect growth regulator. Experientia. (in press).

Retnakaran, A.; Grant, G.G. 1985. Control of the oak-leaf shredder, *Croesia semipurpurana* (Kearfott) (Lepidoptera: Tortricidae), by aerial application of diflubenzuron. Can. Ent. 117: 363-369.

Retnakaran, A.; Grisdale, D.; Percy, J. 1985. Regulation of juvenile hormone metabolism in the Oleander hawk moth, *Deilephila nerii* (L.). Comp. Biochem. Physiol. (in press).

Retnakaran, A.; Hackman, R. 1985. Aspects of chitin deposition and synthesis in the Australian sheep blowfly, *Lucilia cuprina*. Arch. Ins. Biochem. (in press).

Robertson, R.J.; Smith, K.C.; Granett, G.; Retnakaran, A. 1984. Joint action of a juvenile hormone analogue with benzoylphenyl ureas ingested by western spruce budworm. Can. Ent. 116: 1063-1068.

Scott, C.D.; Winston, M.L.; Slessor, K.N.; King, G.G.S.; Grant, G.G. 1984. The biology and pheromone-based monitoring of the dried fruit moth, *Vitula edmandsae serratilineelia* (Lepidoptera: Pyralidae). Can. Ent. 116: 1007-1013.

Sundaram, A.; Leung, J.W. 1984. Physical properties, droplet spectra and deposits of oils used in pesticide sprays. J. Environ. Sci. Health B19: 793-805.

Sundaram, K.M.S. 1984. Residue levels of fenitrothion and aminocarb in the air samples collected from experimental spray blocks in New Brunswick in 1982. J. Environ. Sci. Health, B19: 409-426.

Sundaram, K.M.S.; Nott, R. 1984. Fenitrothion residues in selected components of a conifer forest following aerial application of tank mixes containing Triton X-100. Can., For. Serv., For Pest Manage. Inst., Inf. Rept. FPM-X-65, 14 pp.

Sundaram, K.M.S.; Szeto, S.Y. 1984. Persistence of aminocarb in balsam fir foliage, forest litter and oil after aerial application of three formulations. J. Agric. Food Chem. 32: 1138-1141.

Sundaram, K.M.S.; Szeto, S.Y. 1985. Distribution and persistence of aminocarb in stream water, sediment and fish after application of three Matacil formulations. J. Environ. Sci. Health (in press).

Wilson, G.G. 1984. Pathogenicity of *Nosema disstriae, Pleistophora schubergi* and *Vairimorpha necatrix* (Microsporidia) to larvae of the forest tent caterpillar, *Malacosoma disstria*. Z. Parasitenkd. 70: 763-767.

Wilson, G.G. 1984. Observations of a microsporidian parasite in the white pine weevil *Pissodes strobi* (Peck) (Coleoptera: Curculionidae). Can. For. Res. Notes, 4: 33-35.

Wilson, G.G. 1985. Dose-mortality response of *Choristoneura fumiferana* (Lepidoptera; Tortricidae) to a microsporidium, *Pleistophora schubergi*. Proc. Ent. Soc. Ont. vol. 115. (in press).

Wilson, G.G. 1985. Dosage-mortality response of *Choristoneura fumiferana* (Clem.) to the microsporidium *Nosema fumiferanae*. Can. For. Serv., For. Pest Manage. Inst., Inf. Report FPM-X-68, 7 pp.